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Tree harvesting in fragmented tropical rain forests

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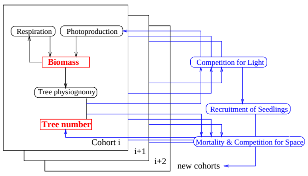
Introduction

Orang-utan dispersing/predating seeds.

Timber harvest in tropical forests is a widely discussed topic. Logging techniques and cycles differ, and thus the damages to the residual forests vary widely. Beside its function as global sink for carbon dioxide a forest logged with methods of reduced–impacts is also expected to increase economic profit compared to a conventional logged forest. Several studies show convincingly that only economic profit will lead to conservation and sustainable practises. On the other hand forest fragmentation is another major thread leading to the extinction of species and habitat losses. A combination of both timber harvest and fragmentation might lead to serve impacts on every ecosystem, but is seldomly studied in research.
In this study we use the rain forest growth model FORMIND2.0 for analysing the effects of various logging strategies on the dynamics of different intense fragmented rain forests.Is there an optimal combination of the logging parameters (method, cycle length) which maximises yields and minimises changes in the forest structure? How serve are logging impacts in fragmented forest structures?

The model FORMIND



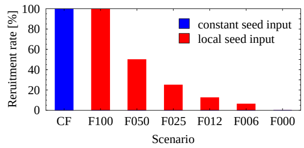
Main variables, processes within individuals, and interacting processes in FORMIND2.0.

FORMIND2.0 is an individual-oriented process-based forest growth model to simulate the spatio-temporal dynamics of uneven-aged mixed forest stands (Köhler & Huth 1998, Kammesheidt, Köhler & Huth 2001, Köhler et al. 2001).
The model describes forest dynamics as a mosaic of interacting forest patches of 20 $m^2 \times 20$ m^2 in size. Within these patches trees are not spatially-explicit distributed, and thus all compete for light and space following the gap model approach. The carbon balance of each individual tree including photosynthesis and respiration is modelled explicitly. Thus, we can match measured diameter increment for different tree species, sizes and light conditions accurately. Allometric relationships connect the aboveground biomass, the stem diameter, the tree height and the crown dimensions. Details of growth processes are taken from related model FORMIX3-Q (Ditzer et al. 2000). Beside increasing mortality through self-thinning in dense patches one of the main processes is gap creation by falling of large trees. This process as well as seed dispersal from mature trees interlinks neighbouring patches with each other. Seed production rates of mature trees are effective rates regarding recruitment of seedling at a diameter threshold of 1 cm, where seed loss through predation is already incorporated.

Species grouping

We simulate forest dynamics of a dipterocarp lowland rain forest in Sabah, Malaysia. 468 shrub and tree species of that area were assigned to 13 different plant functional types (PFT) based on their successional status (early, mid-, late) and maximum height at maturity (shrubs, understorey, lower canopy, upper canopy, emergents). A species list is available at http://www.oesa.ufz.de/koehler (Köhler, Ditzer & Huth 2000).

Forest fragmentation

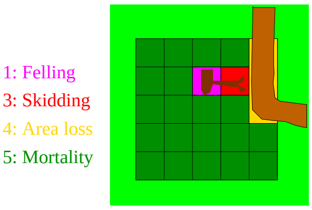


Definition of the fragmentation scenarios.

In the modelling of closed forests the recruitment was supplied with constant inputs of seeds into a seed pool. The recruitment module of fragmented forests contents a seed pool supply from local mother trees. We consider our simulated area embedded in a larger area of similar forest structure and do not consider edge effects. However, field studies have shown a decrease in the recruitment capability of forest fragments caused by losses of seeds and a reduction of seed dispersing animals. Seven scenarios of different fragmentation intensity and thus recruitment capability ranging from a closed forest to fragments without any recruitment were defined and analysed.

Logging impacts

Two different logging methods were applied – reduced–impact (RIL) and conventional logging (CON). Both differ in the damages to the residual stands as shown in the following Figure and Table. Only trees of mid- and late successional species with a diameter $\geq$ 60 cm are logged. Logging cycles lengths between 20 and 80 years were analysed.



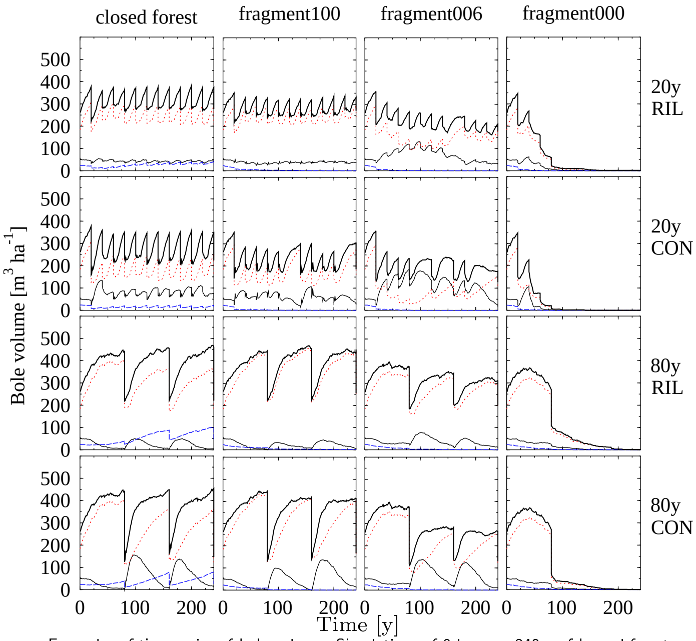
Spatially explicit logging damages.

Impacts of different logging scenarios.

	Effects	RIL	CON
1	Felling damage	∼crown size	
2	Felling direction	gaps	random
3	Skidding damage	25%	55%
4	Area loss	12%	33%
5	Mortality 10yr after	× 2	× 3

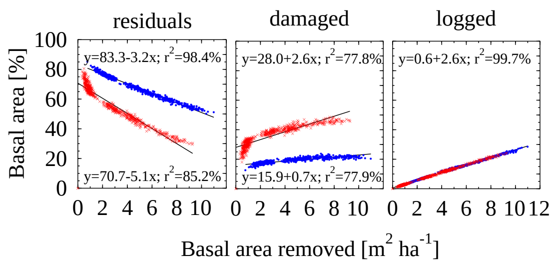
Results

Timber extraction in forest fragments led to the immediate extinction of late successional species after a few logging operations. The standing bole volume declined with time in fragments and the species composition was highly altered under conventional logging methods. Thus, the habitat structure of the forest for animal species was altered strongly by both fragmentation and logging impacts. Feed backs of the habitat losses on the forest dynamics might be even more serve in those cases than assumed here.



Examples of time series of bole volume. Simulations of 9 ha over 240 y of logged forest. Variation of logging cycle (20 y; 80 y), logging strategy (RIL; CON) and fragmentation intensity (see text for details). **Total**, early successional spp., mid-successional spp., late successional spp.

The harvest yields were maximised in logging cycles of 40–60 y and reduced–impact logging strategy. A simple theory for the relationship between yield, logging cycle length and impact intensity confirms this result.
In the scenario of highest fragmentation intensity the bole volume increased for the first decades and the forest dieback following after the first logging operation was not detectable within those years. This indicates that different anthropogenic impacts might add up to most serious situations.
Simple relationships of logging impacts as a function of logging intensity emerge from our analysis. They are easily comparable with field data and validate our analysis as reasonable. Furthermore, they are a practical tool for estimating the impacts of logging disturbances on the residual forests.



The effects of different logging strategies (reduced–impact, conventional) and intensities on the forest. Basal area (residuals, damaged, logged) as a function of removed basal area.

However, our simulated logging impacts did not consider impacts on the forest floor, which might delay post–logging sapling establishment. Thus, we understand our results as optimistic.

Conclusions

FORMIND2.0 is able to analyse various logging strategies with respect to their impacts on the residual rain forest. Reduced–impact logging strategies with medium cycle length gained the highest timber yields. However, in highly fragmented landscapes timber extraction led to massive extinction of tree species. Keeping the present fragmentation processes in mind future analysis should consider forest edges and the increased tree mortality near those edges.

References

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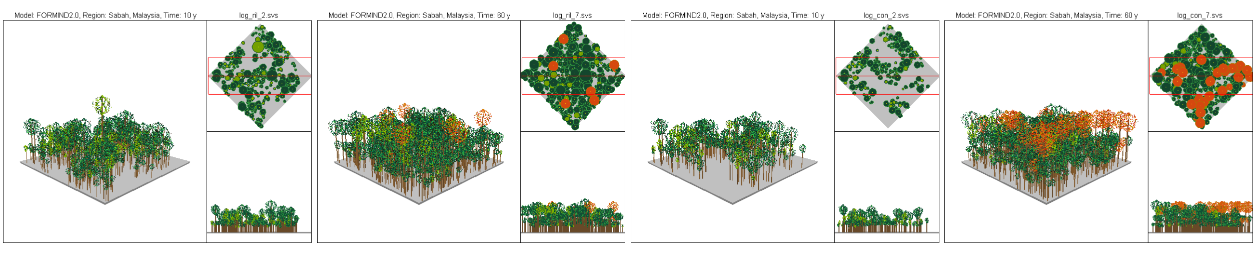
Below: A closed forest stand of 1 ha directly after (50 y after) reduced–impact (left) and conventional (right) logging is visualised using Stand Visualisation Software (SVS). All trees with a diameter $\geq$ 20 cm are shown. Color indicates successional status: early successional spp., mid-successional spp., late successional spp.



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